15:41:05 OCA PAD INITIATION - PROJECT HEADER INFORMATION 09/15/94

Active

Project #: E-25-530 Cost share #: Rev #: 0
Center # : 10/11-6-P5345-0A0 Center shr #: OCA file #:
Work type : INST
Contract#: LTR DTD 940815 Mod #: Document : OTH
Prime #: Contract entity: GTRC

Subprojects ? : N CFDA:
Main project #: PE #:

Project unit: MECH ENGR Unit code: 02.010.126
Project director(s):
DICKERSON S L MECH ENGR (404)894-3255

Sponsor/division names: CDS INTERNATIONAL / NEW YORK, NY
Sponsor/division codes: 500 / 217

Award period: 940919 to 950319 (performance) 950319 (reports)

Sponsor amount	New this change	Total to date
Contract value	6,000.00	6,000.00
Funded	6,000.00	6,000.00
Cost sharing amount		0.00

Does subcontracting plan apply ?: N

Title: TRAINING PROGRAM FOR MS. S. USHA IN MACHINE VISION

PROJECT ADMINISTRATION DATA

OCA contact: Jacquelyn L. Bendall 894-4820

Sponsor technical contact	Sponsor issuing office
PETRA WOLFF	PETRA WOLFF
(212)760-1400	(212)760-1400
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NEW YORK, NY 10001-5010	NEW YORK, NY 10001-5010

Security class (U,C,S,TS) : U ONR resident rep. is ACO (Y/N): N
Defense priority rating : N/A N/A supplemental sheet
Equipment title vests with: Sponsor GIT X

Administrative comments -
INITIATION OF PROJECT.

GEORGIA INSTITUTE OF TECHNOLOGY
OFFICE OF CONTRACT ADMINISTRATION

NOTICE OF PROJECT CLOSEOUT

Closeout Notice Date 05/04/95

Project No. E-25-530 — Center No. 10/11-6-P5345-0A0

Project Director DICKERSON S L — School/Lab MECH ENGR

Sponsor CDS INTERNATIONAL/NEW YORK, NY

Contract/Grant No. LTR DTD 940815 — Contract Entity GTRC

Prime Contract No. ______

Title TRAINING PROGRAM FOR MS. S. USHA IN MACHINE VISION

Effective Completion Date 950319 (Performance) 950319 (Reports)

Closeout Actions Required:	Y/N	Date Submitted
Final Invoice or Copy of Final Invoice	Y	
Final Report of Inventions and/or Subcontracts	N	
Government Property Inventory & Related Certificate	N	
Classified Material Certificate	N	
Release and Assignment	N	
Other ______	N	

Comments ______

Subproject Under Main Project No. ______

Continues Project No. ______

Distribution Required:	
Project Director	Y
Administrative Network Representative	Y
GTRI Accounting/Grants and Contracts	Y
Procurement/Supply Services	Y
Research Property Managment	Y
Research Security Services	N
Reports Coordinator (OCA)	Y
GTRC	Y
Project File	Y
Other ______	N
______	N

E-25-530
1

DG / IND / 91 / 025 / 31-04

USHA.S

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FINAL REPORT

19. Dec 1994 To 10 March 1995.

Georgia Institute Of Technology
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Dr. STEPHEN L.DICKERSON

Usha | Dr.Stephen L.Dickerson | 10 March 1995

Purpose of the training

Started the work on machine vision for Robotics application at CMTI in the year 1990. Basic concentration was given to software development on a PC based system with frame grabber having resolution of 512 X 512 X 8 bit and a video camera with 384 X 492 resolution. We were successful in developing basic vision algorithms and application packages for part identification and inspection tasks. The same is extended to Macintosh platform . But we could not successfully implement vision for real time industrial application mainly due to high cost and poor processing speed.

The training at Georgia Institute Of Technology gave a good insight into the use of different lighting strategies which is the heart of any industrial vision application. Lot of research has taken place in the area image sensor development that replaces the traditional TV camera which is highly expensive for its high resolution. Also the frame rate is slow (30 frames/sec) . The image sensor consists of a detector associated with driver circuit and an analog to digital converter that converts image data directly into useful digital information.

It is realized that for most of the purposes a resolution of 165 X 200 is adequate as against 512 X 512. Where application calls for higher resolution , it is preferable to have multiple head. parallel processing paradigm instead of a single higher resolution sensor , with a single processor to achieve the desired high resolution at high speed.

There is no unique solution for vision task. Each element of the vision system varies greatly from one application to other. Standard setup is good only for proto typing and testing The training gave some exposure to approach a given problem starting from the selection of suitable optics, lighting, hardware architecture and processing. If it is high precision measurement task, selecting suitable calibration technique to correct for possible errors.

Visited some industries who are extensively using machine vision. The details are included at the end of this report. One of the industry is AT & T Networks system where they mainly manufacture optical fiber for communication purposes. They had requirement to measure the diameter of the VAD core using machine vision. Presently it is done manually using optical measurement system. The details of project is presented in the next section.

VAD Core and Jacket Soot Diameter Measurement

Vapor-phase Axial Deposition , VAD , is one of the several processes used in the manufacturing of silica based fiber preforms. The VAD process employs a deposition of soot particles. Particles are formed either in the torch reaction zone by flame hydrolysis or on the surface of the soot boule. A porous soot boule is formed in layers of doped and undoped silica particles deposited on to a vertical rotating target from a stationary torch. The soot boule is dehydrated and consolidated in a high temperature furnace. Consolidated body is elongated into a rod and jacketed utilizing an oversooting VAD process. The jacketed soot body is consolidated and elongated. The elongated jacket (preform) is prepared for the fiber draw process. Fiber draw stretches the preform into optical fiber for communications.

Vision system is used to measure the outer diameter of the porous core and jacket soot boules , before going into the furnace for consolidation and during the deposition process.

Task:

The task is to measure the diameter, d of the VAD core and jacket soot. It is necessary to find the minimum , maximum, and average diameter of the core and the jacket along the entire length, l, (fig. 1) with an accuracy of 0.5mm and record the data in ASCII file.

System Requirements:

These are provided requirements for range of sizes of the core and jacket soots, and the distance that is allowed from the soots to the vision based measurement system (stand-off distance). All measurements are in millimeters.

	Diameter D		Height, L	Stand-Off Distance	
	Min	Max	Max	Min	Max
Core Soot	80	130	1200	150	4000
Jacket Soot	190	280	1200	150	4000

Proposed Method of Measurement:

Lighting scheme

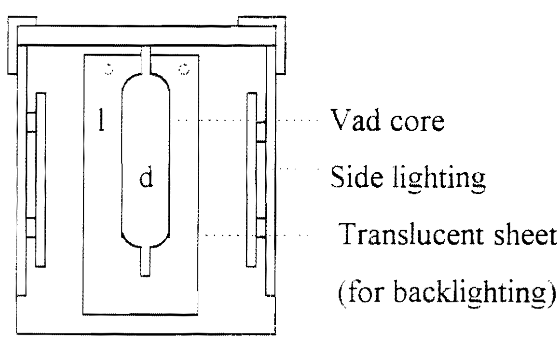


Fig-1

It is proposed to have florescent tubes with high frequency ballast (25khz) on both sides of the soot that would (1) light the soot uniformly over the entire length using a black background or (2) light a white background over the entire length and not illuminate the soot. Since the VAD core is snow white in color, slide lighting would be ideal, whereas for the jacket soot, which is transparent backlighting would be necessary. Also it may be necessary to have sheet of translucent material between the florescent bulb and the soot.

Vision System.

Two cameras or vision systems with substantially parallel optical axes are positioned to view the two edges of the soots. Depending on the range of diameter to be measured in a particular instance, the cameras are moved horizontally in increments of 20mm so as to most nearly line with the soot edges. Five positions for each vision system is proposed. The motion of the vision system would be automatic.

Camera Position	Soot Diameter	Camera Separation
1	80-120	100
2	120-160	140
3	160-200	180
4	200-240	220
5	240-280	260

The cameras are moved together vertically to make measurements along the entire length of the soots. Both motions are achieved through stepper motors coupled to the vision system through ball screw mechanisms. The control for the stepper motor are provided by the vision system or the host PC.

Calibration

The system is to be calibrated with a dummy target soot (calibration soot) for each range. The calibration scaling factors are computed automatically from the target for each vision system. Because the vision systems are moving horizontally between fixed, and repeatable positions. the mechanical inaccuracies of the vision system mounting and motion system are minimized. A permanent pattern of fiducials on the background may be desirable to verify that the motion of the vision system and other geometric variables have not changed.

Analysis of Errors and System Accuracy

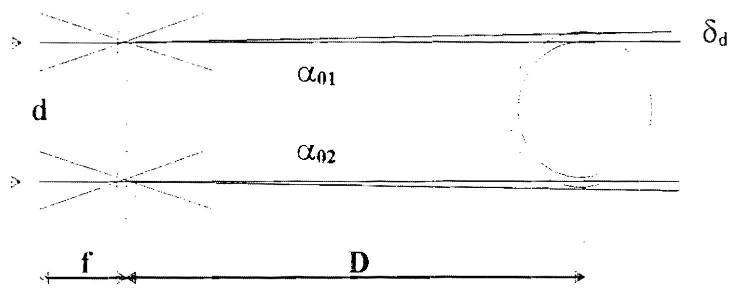


Fig -2

The considered sources of error in the diameter measurement are:

1. Parallax error. This is a result of (1) variation in distance between the soot and the camera, (2) the difference between the vision system center distance and the diameter of the soots. If either item 1 or 2 are zero there is no parallax error. Item 2 is the reason for the proposed five horizontal positions of the vision systems.

2. Subpixel edge computation error. This is the result of both the subpixel position measurement and any non linearity / non-repeatability of the vision hardware. It is believed that this error can be reduced to 1/10 pixel for cases where the hardware is directly using the hardware pixel position on the detector. For direct digitization system e.g. the DVT systems, this would be the case, and for standard camera systems, it should be the case if row to row distance is used since the column to column digitization is the result of an electronic sampling of an analog signal.

3. Calibration error. This is the result of the above two sources of error when the system is calibrated, and any mechanical, thermal, or electronic drift after the calibration.

Now lets consider the magnitude of these errors.

A linearized analysis is used here for simplicity. That is, assume small angles where

$\tan(\alpha) = \alpha$. This assumption is used only for the error estimation. In calculating the true diameter of the soot, the actual trig functions including the effect of edge position movement would be included.

The computation of the diameter is approximately

$$d = \quad d+D(\alpha_1-\alpha_2)$$

$$d+D(\ \delta/\ (D+\Delta\ ) +\varepsilon_1 +\delta/\ (D+\Delta) +\varepsilon_2)$$

$$d+ 2\delta + D(\varepsilon_1+\varepsilon_2) -2(\Delta\delta/D)$$

where...The last two terms in the equation represent the subpixel edge measurement error and the parallax error respectively. For conditions:

$D = 500$ mm

$\Delta = 2$ mm

$\delta = 20$ mm

$\varepsilon = 5.73E-5$ (=2.64mm /24mm/192/10)

Parallax error =0.16 mm

Subpixelization error = 0.0575 mm.

A strictly additive error has been used for subpixelization. In fact, the errors are random variables. Thus, the error of 0.1 pixel per measurement, if taken as 3 sigma error, should be added using RMS.

The calibration error should have a very low parallax error, since the calibration targets should be designed and built to have essentially zero motion in the direction of D, e.g Δ =0 mm. The subpixelization error should be no greater than for the measurement itself. In calibration, multiple scans of the calibration target would be made, and average values used for the diameter scans of the calibration target would be made, and average values used for the diameter measurements, reducing the calibration error, and verifying that the system was working properly.

Thus the projected error in a diameter measurement is expected to be less than 0.275mm (0.16 +2*0.0575)

Lets consider a case however, where only one vision system was used. Consider the following conditions

D = 2636 mm (sufficient to give FOV of 290 mm)

Δ = 2 mm

δ = 140 mm (this is one-half of the maximum diameter of the soots)

ε = 5.73E-5

The parallax error = 0.2124 mm
Subpixelization error =0.3031 mm

This is within the striking distance of being acceptable. It would be acceptable if parallax could be assured of being less, that is the motion toward or away from the vision system less than 2 mm., and if calibration could be assured to be much better than 1/10 pixel. The latter is likely to be possible if multiple scans are taken of the calibration target.

Other ways of increasing the subpixelization result is to

1 Use a higher resolution camera, either line scan or other with an assured pixel stability.
2. Use two fixed cameras. That is don't have five positions.

Finally it is concluded that a single vision head system could be built with a vertical traversing mechanism capable of transporting two systems if necessary and that illumination system be built with the flexibility to go easily from side illumination to back illumination. Two calibration soots would be built for extremes of size.

The vision system was supplied by AT&T. The system consists of a PC with a frame grabber board plugged on to the PC bus. The frame grabber board was from Imaging Technology Inc. with resolution of 512 X 512 , and 256 gray shades. ITEX OFG is the library of image processing functions for use with the image processor. Application program written in C is linked with this library, to make use of functions like image acquisition, display, and to retrieve the image from the frame memory to system memory.

The Structure of the code is divided into four major parts.

1. Input / Output module.
2. Measure Module.
3. Calibration Module.
4. Motor control Module.

Input/ Output Module :

This gives the user option to input either through keyboard or from a file data such as the

row_start.
column_start
width
height
# of row increments.
Edge sensitivity, threshold for rising or falling gradient.

The output is the left edge and right edge position for each edge. This data is collected over the entire length of the soot, and table is created that gives the left, right edge in pixel, its row position and the diameter in mm. This table is later used to give such details as minimum , maximum, average diameter and variance over the specified range.

The image of the soot is displayed on a TV monitor with the detected edge highlighted. The corresponding diameter is also displayed in the overlay graphics buffer.

Measure Module.

The image is acquired into the frame buffer. Then it is brought to the system memory 4 line at time and the following gradient mask is applied to detect the edge.

0 1

0 1

0 1

0 1

This detected edge position goes into a subpixel algorithm where the edge is computed to subpixel accuracy by fitting the gradient pixel values at each row to a parabolic equation. Once the table of edge positions are collected , the following steps are followed to calculate the actual diameter of the soot at each row position.

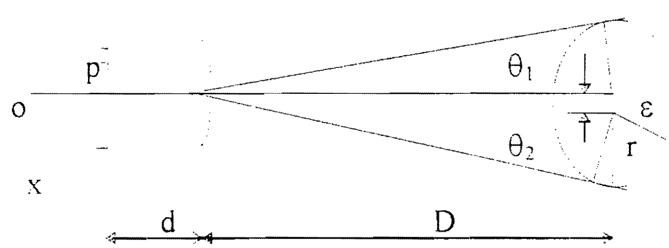


Fig-3.

$$\sin\theta_1 = \frac{r-\varepsilon/\cos\theta_1}{D-\varepsilon\tan\theta_1}$$

$x1 = d\tan\theta_1$ [assume straight light through optics. distortion.]

$n_1' = x_1/p$ [number of pixels from x=0, corrected for distortion.]

$n_1' = (1+cy+kl_1^2)\, n_1$ [n is measured # of pixels from center of the detector. l_1 is measured radius in x.]

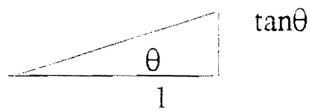
$$\sin\theta_2 = \frac{r+\varepsilon/\cos\theta_2}{D+\varepsilon\tan\theta_2}$$

$x_2 \quad = -d \tan\theta_2$

$n_1' \quad = x_2/p$

$n_2' \quad = (1+cy+kl_2^2)\, n_2$

Forward computation Given l_1.,n_1..l_2.,n_2 determine 2r.



$\sin\theta \quad = \tan\theta/(1+\tan^2\theta)^{1/2}, \qquad \cos\theta = 1/(1+\tan^2\theta)^{1/2}$

$r_1 \quad = (D-\varepsilon\tan\theta_1)\sin\theta_1+\varepsilon/\cos\theta_1$

$r_2 \quad = (D+\varepsilon\tan\theta_2)\sin\theta_2+\varepsilon/\cos\theta_2$

$r_1+ r_2 \quad = (D \sin\theta_1+ \sin\theta_2)-\varepsilon(\tan\theta_1\sin\theta_1 - \tan\theta_1\sin\theta_1 -1/\cos\theta_1+1/\cos\theta_2)$

ε term is reduced to

$= \varepsilon\ (co\theta_1 - \cos\theta_2)$

In our case D =2.6met

$\varepsilon \quad < 0.01$met

$\theta_1 \simeq \theta_2 \quad = 5.31 x 10^{-2} \qquad \tan^{-1}$ 140/2636)

$\theta_1 - \theta_2 \quad = 2\varepsilon/D = 8 x 10^{-3}$

ε term $= 0.01\ (\cos(5.71 x 10^{-2})- \cos(4.91 x 10^{-2}))$

Hence we should be able to neglect ε term in computation of radius.

Calculate θ using $(x_1- x_1)/2$ in place of x_1 and x_2

$\Delta\ (r_1- r_2)= 2.6(2\sin 5.71 x 10^{-2}- \sin 5.71 x 10^{-2}- \sin 4.91 x 10^{-2})$

$= 1.6\mu m$

Direct calculation gave.

$2.6 x 8.49 x 10^{-7} = 2.21\mu m$

So we can ignore this effect also.

Finally we can state that if we line up the axis of the soot with the axis of the vision system, we can make calculations as follows:

$x = d\tan\theta$ [this gives θ]

$r = D\mathrm{Sin}\theta$.

$(x_1 - x_1)/2$ can be used for x

Calibration Module.

Calculation of calibration factor is done using a uniform calibration target.

$$n = n_0(1 + c(y - y_r) + kl^2(y - y_r))$$

where n is the actual radius of the target after correction.

n_0 is the measured pixel radius.

c is the distortion factor due to variation in D.

k is the radial distortion factor.

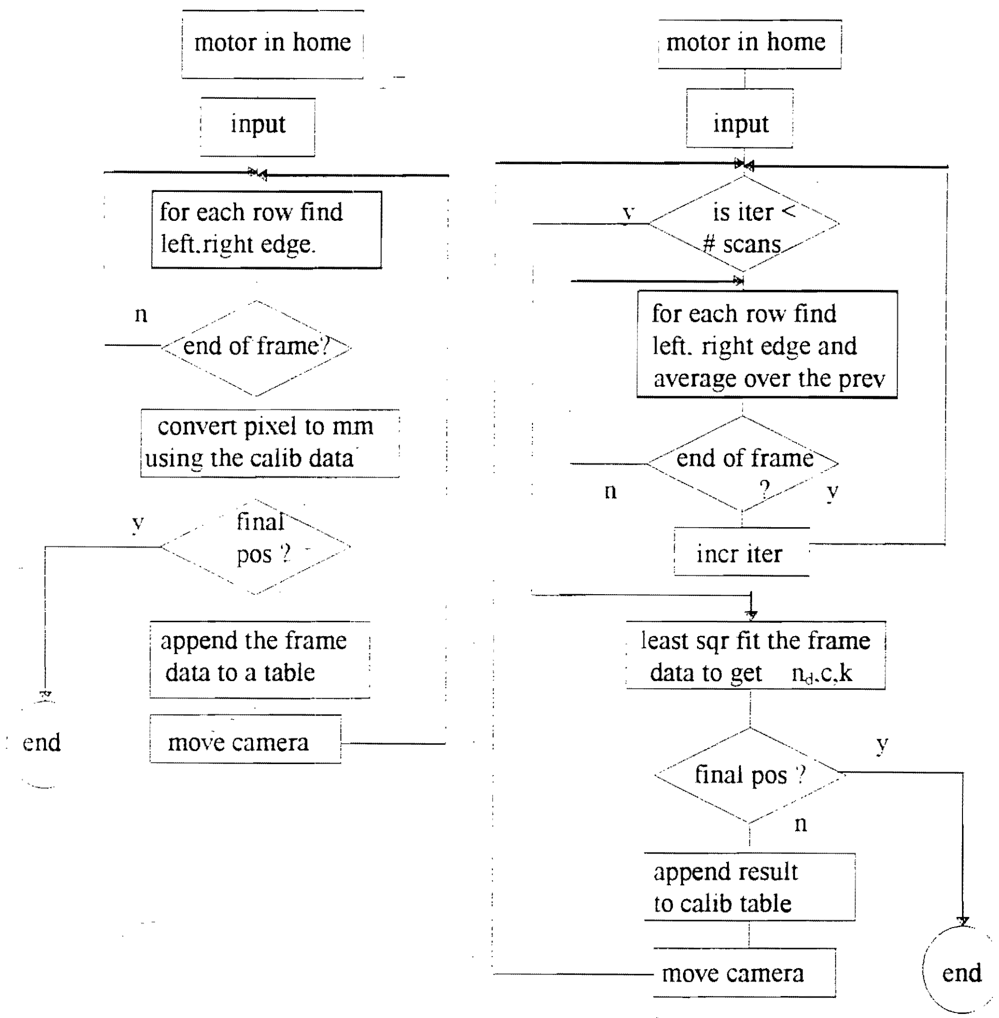
c and k are to be computed from the above equation. The equation is solved for three unknowns using linear regression method. The values obtained for both k and c for each frame are used in the measurement to correct for errors due to radial distortion in the soot and due to variation in D.

Motor Control Module.

Stepper motor with a ball screw mechanism is used for the vertical traversal. The camera is mounted to the slide. Stepper drive is connected to PC through RS232C serial communication line. Hardware limit switches are used for end limits of the traversal.

To start with the camera is moved up till it reaches the top limit, from which the measurement begins. Every time the camera takes a picture and process it , moves to the next position and repeats the process till the entire length of the soot is being processed.

Flow chart for the measurement and calibration process are given below



Measurement Calibration

The process is same during both calibration and measurement, except that duringcalibration the target is assumed to be very accurate and uniform diameter throughout the length. Also during calibration multiple scans are used and pixels are averaged to have better accuracy.

In this module , during initialization, the communication port is set to correct baud rate, the # of data bit, # stop bit and parity are set to desired value. Also the velocity and acceleration desired for smooth movement are set during initialization. Then the motormove command is issued by sending the desired number of pulses and the direction of rotation through RS232C port.

Visit To Universal Instruments Corp. ***Binghamton NY.***

High density packaging and assembly.

Presented by Ron Lasky, Director of Advanced Technology.

Assembly machine design.

Len Yeager

Tour of machine shop.

Len Poch, responsible for Machine Vision.

Tour of C4 assembly lab.

Peter Borgensen.

Visit to IBM ***Endicott NY***

Tour of assembly line.

Tien. Y. Wu

Flip Technology.

Presented by Mary cretekos.

Materials for circuit packaging

Presented by Michael A. Gaynes.

Tour of fine line flex facilities

Dan Nash, -Bill Mallery.

What I learnt from the trip.

Surface mount leadless semiconductor technology has been developed to meet the portable electronic products. The advantages are smaller size, higher package inter connect density, higher test and solder assembly yields due to use of pre applied solder bumps and greater technology extendibility in the area of high speed integrated circuits, multichip modules and fine pitch soldering.

This technology has moved the leaded plastic packaging from 100mil pitch DIP to 50mil pitch plastic leaded chip carrier (PLCC) to 40mil(1.0mm) pitch quard flat package (QFP). QFP have evolved to the current commercially available state of art 20mil pitch package. According to Universal's report this evolution has resulted in 93% reduction in PCB area consumed by a 64 pin leaded plastic package.

Assembly equipment for chip placement, adhesive placement, positioning is very precise. It is able to handle flip chip requirements. The current models provide combination of vision based chip/ package alignment for precise placement. The vision systems are very fast with placement rate of 0.25sec/chip at an accuracy of the order of 10μm.

There is a great emphasize on the need for higher resolution vision system at modest cost at greater computing speed. As the dimension become smaller and smaller, there is going to be greater need for vision feedback.

Typically circuit boards associated with fine pitch assembly have vision identifiable features or fiducials. These fiducials have known location relationship to the placement sites of the fine pitch component.

The fiducials located at the corners of the circuit boards are used to determine the gross location and angular registration of the board relative to the placement machine. These fiducials allow placement machine to compensate for variations in registration of the board within the placement machine. This was accomplished by a downward looking camera attached to the placement head structure.

The camera system having a known location with respect to machine x,y coordinate system is positioned over each fiducial to be observed. An automated vision system process then determines the fiducial in machine coordinate system.

Two elements critical to the placement are,

1. Ability to accurately recognize fiducial and compute its location.
2. Ability of the positioning system to locate camera optics accurately over the fiducial.

The chip is viewed after pickup by another upward looking camera, that captures image information of each lead of the component and their lead location to each other, screening criteria was given by the operator for rejection. The last process was to position the chip over the site and place it.

The architecture followed by universal was observed to be two layer. The lower layer was a bit serial processor based. All low level processing on individual pixel are done at this layer using a single bit cpu. The result of processing are trasfered to the next layer, which acts like a host processor and does higer level data interpretation.

Universal's consortia on UFP(ultra fine pitch) and BGA/DCA was very successful in results and involvement of many companies.

In IBM they are using conductive polymers for flip chip attach. The fine line flex process at IBM appears to be great war to make circuit at densities required for direct chip attach. The process starts with a polycarbonate sheet in roll form and fabrication of the complete flexible circuit is maintained in roll form. so the material handling is convenient Sheet had registration holes at edges . They moved like movie film. Flux circuit is latter attached to substrate. Then solder bumps are welded to the circuit.

Another attraction was the very low stiffness of the substrate. This reduces the stress on the chip.

Vision guidance and inspection of all operations leads to a situation where one may not continue to rely on machine precision, thus reducing the cost/ performance. Needs to concentrate on making the technology available at low cost so that flip chip assemblies become the lowest cost alternative. So paradigm that uses parallel architecture with multiple head viewing a single image speeds up the process and results in higher resolution. Also use of DSP in place of general purpose processor would be a better alternative for real time image processing application.

Visit to Allen Bradley Unit *Dublin.*

Tour of assembly shop (PLC production unit)

Jack Bell. Manufacturing Engineering Manager.

Most of their assembly stations are using through hole technology. They are recently switching over to surface mount technology. They are using Vision system developed by universal in their surface mount assembly cell.

Courses Attended

Database design that covers the E-R diagram from the system requirements, relational algebra and database design. SQL, relational calculus, functional dependency and normalization, network model and concept of object oriented database design.

Operating System Design that covers batch processing, multiprocessing, multitasking,, and real time operating system. Concept of threads , communication links, memory management, file structure, and distributed system. The course had project involving programming threads. Incorporated a simple mailbox consumer/ producer routine.

Studied the general concept of Networking Pcs. Used Mosaic browser to access internet and collected information on various topics related to vision and computer software. Created man pages using html (hypertext markup language) that includes text and graphics and linked to number of branches depending on topic clicked. The idea could be extended for storing the information on various topics involved in the manufacturing environment in different pages and links could be established between related topics for search.. This results in a user friendly browsing of huge collection of related data.

Conclusion

It is observed that machine has a great potential in manufacturing industry especially the electronic packaging industry. Since it the area of current interest in US industry, I suggest that in CMTI we should form a good group to do research in this field in collaboration with research institute like Georgia Tech and industries like DVT and universal..

After going back to India, my focus will be to develop simple industrial vision application using integrated vision unit and extend the research in this field to integrate to a CIM cell.